Discussion

2nd Session: REPAIRS AND RECONSTRUCTION OF THE STRUCTURES

DISCUSSION

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"Structural Repair of Monumental Masonry Buildings"

CROFTS

I would like to ask if you had any problem in drilling these very long holes to make certain that the drill holes went in the right place and did not veer off to one side or the other.

MENDITTO

The drill can depart from its course owing to its flexibility and its dead load when it meets different or differently arranged materials (i.e. stones, oblique faces of stones, elements of existent stirrups, points of contact between the stonework and the wood, etc.). In this case one inserts some little steel springs, normally arranged at the distance of 3 ÷ 4 metres from each other, through holes made for this purpose in the stonework in order to check that the way of the drill is in the right direction.

VELKOV

I would like to ask you concerning the concept of the repair, because sometimes you checked the model of the structures. Did you use the system of repair only to increase the resistence or also to increase the ductility? What was the principal concept of the repair? Did you make any analytical or experimental research in that connection, how to improve, how to increase the ductility?

PETROVSKI

I think that the repairing of historical monuments or of old buildings which are still in use poses the same problems. These types of structures survive for many centuries experiencing probably a great number of smaller earthquakes; they survive them with small of severe damage. There is really need to make structural changes to increase the ductility or strength of these structural systems? In my opinion it is almost unacceptable to increase the ductility, or it is very difficult; it is simply not feasible, not economical. I

would say that it is essential that we increase the strength of these structural systems and do not change their dynamic properties, because the empirical knowledge upon which our science is mostly based, is that they really survive for centuries.

MENDITTO

A proper repair requires a preventive historical knowledge in order to outline the structural pattern of the period techniques and the possible distributive and structural changes undergone by the masonry during its life. Such point of view is particularly important in order to outline volumetrical and distributive changes. Almost always the lack of original technical works turns the researches to not always satisfactory analyses. As matter of fact these researches must be confined within definite limits because of the size of the construction and the need of not modifying some monumental features (i.e. decorated floors) and the equilibrium of the construction, often already heavily damaged by the earthquake. A careful knowledge of the construction behaviour is also required at both technological and static level. This field disregarded for a long time because of the concrete technique nowadays reopens to operators of the field. Fortunately a wide part of the traditional culture in masonry survives though it is prevalently empiric. The main goal of some remarkable researches is to check these principles and to arrange them into an organic theory. In Ancona we are working in this direction with a view to suggesting some behaviour models that we are carrying out with the advanced techniques of the structural analysis (i.e. finite elements). Of course some remarkable difficulties arise (i.e. the lack of proved constitutive laws for masonry) which we try to overcome with systematic and wide experiments.

It follows that several of the outlined repairs make use of a rational professional experience instead of sophisticated theories. Local and global checks performed as far as possible mainly to assure the statics and to restore the damaged constructions. Experiments were performed sometimes as far as possible. This is the case of Urbania episcopal seminary. Small masonry pillars were built using the same original technique and then crushed. The limit stress was 45 $Kgcm^{-2}$ and 120 ÷ 135 $Kgcm^{-2}$ respectively before and after the repair. Our philosophy is to respect the architecture and to give at the same time to the construction a greater resistance than the initial one without any change in the whole elasticity.

It is pointed out that the suggested repairs consist mainly of sewing of different separated pieces using prestressed concrete tendons and mortars with additives. Therefore no change takes place in the original material where the elastic properties remain unaltered. Moreover the limited extent of the sewings cannot modify the original rigidity of the whole construction.

In our opinion a check of the whole ductility involves insuperable theoretical difficulties mainly because of the complex and not always known distributive pattern and of the tridimensional behaviour of these constructions.

An experimental approach can be attempted making use of an electric-dynamic exciter. Unfortunately the experimental results are confined to the chosen pattern of the repair. Moreover it is not possible to make a comparison with the original construction no more available because of the damages of the earthquake.

LANE

I have heard that steel was used for repairs in the case of the Parthenon and adjacent buildings in Rome. This was, I think, done in the 1930's. And I believe that now the deterioration of the buildings is greater because of the use of steel than it would have been without it, and I would like to know if you are satisfied that the use of steel in these cases will be satisfactory in the long term.

MENDITTO

Steel appears to be useful in the adopted repairs as it allows sewing and bracings otherwise impossible to realize because of its flexibility. We think the damage that Mr. Lane talked about depended upon oxidation processes, that took place because of lack of steel protection. These steels, even though exhibiting mechanical properties better than the current ties, were employed with the same technique as the ties. Consequently the masonry hygroscopicity and the presence of lime accelerated the oxidation of the steel, both by the reduction of its diameter (this process being quickened by the smaller sizes in respect of those of ties) and by mechanical breaking on the stonework. On the contrary we make use of a steel, protected against the oxidation by an oiled plastic sheath and by mortars with additives.

CROFTS

I saw on the slides you had some jacks. But the jacks appeared to be in the middle of the reinforced concrete. I wonder, did you lose the jacks or did you manage to recover them?

Dealing with this kind of buildings one is often very concerned about building movement. I wonder if you had any checks made on the movement of the building during repairs, using strain gauges or plumbing arrangements to make certain that any movement during repair was detected.

MENDITTO

The jacks are embodied in the concrete. When necessary (i.e. in the change of floor) the movements of the structure are followed during the repair by means of some stations of topographic survey, located in the most signif-

icant points of the structure. None dangerous movement is pointed out.

The injection pressure must be variable and limited by the strength of the masonry type. Also the tensile stress of tendons is related with the sizes of anchorage plates. The latter depend upon the architectonic requirements (possibility to dissimulate them) and the strength of masonry.

VELKOV

Concerning the increasing of the resistance: did you check anything which is connected with the foundation and the pressure in the soil, because with this repairing it is very clear that you increase the resistance of the whole structure. What will happen in the soil condition in the next earthquake, and also with the redistribution of the damage in the structure?

MENDITTO

We always worked in order to keep the same load distribution on the foundation to improve at the same time the ground with a sewing work (i.e. the use of micropoles). In all cases the efficiency of the whole structure and the interaction between the foundation and the overhanging structure were checked.

It is very hard to foresee the construction behaviour at next earthquake, since the earthquake features cannot be foreseen. At most some inertial effects can be simulated like those derived from the earthquake (i.e. by suitable adjustment of the road traffic, by controlled explosions, etc.) in the structure and in the ground and afterwards the dynamic behaviour both of the repaired structure and the improved ground can be pointed out by the recording vibrations. In this way we have experimental data about proper modes of structure vibrations. The latter transferred into a suitable mathematical behaviour model may supply useful information with regard to the dynamic response of the whole structure when the acceleration spectrum of the design earthquake is known.